SYSTEM AND METHOD FOR USING FOR A SCHEDULER BASED ON VIRTUAL FRAMES

The present invention relates generally to communication systems, and more particularly, the present invention has particular application to the field of wireless

5   communication systems and in this aspect relates to a scheduler and related method for efficiently granting polls to upstream and/or sidestream traffic and sending downstream frames.

Scheduling is essential in providing quality of service (QoS) in data networks where multiple users share common resources. This is especially true in the context of

10   wireless links. That is, the time-varying nature of wireless links presents great challenges in the design of scheduling policy in wireless data services because of the scarcity of radio resource and the time-varying nature of radio quality. Currently, most scheduling policies are dependent on the queue length or arrival rate or time stamps present in a transmitted medium access control (MAC) frame and do not consider the channel capacity. This

15   would suffice if the channel capacity to all users were constant as is the case in wireline systems. However, in the context of wireless networks, a drawback of these schemes is that they always result in an under-utilization of the wireless resources by not accounting for the channel capacity (i.e., the channel condition and continuously varying transmission rate).

20   Currently, the 802.11 MAC offers a simplified model, referred to as a "best-effort" model. In the simplified scheme, all frames receive the same level of service with no distinction for frames from different applications. In accordance with the model, an attempt is made to forward frames as soon as possible, but makes no quantitative commitments about the quality of service (QoS) provisioning. But with the advent of

25   802.11e, which is a quality of service MAC, a scheduler is need that will guarantee the QoS requirements for different streams.

Accordingly, there is a need for a scheduling policy that can be incorporated on top of the IEEE 802.11e/D3.3. draft standard enabling an QoS access point (QAP) to take into account the QoS requirements of the stream and schedule appropriately.

30   The present invention is directed to a scheduling method based on virtual frames for use in a wireless local area network (WLAN) that enables a QAP to seamlessly operate between granting polls for upstream and sidestream traffic while sending downstream

frames. A key feature of the scheduling method of the invention is that the scheduling method generates virtual frames to create transmission opportunity durations for granting polls for the upstream and sidestream traffic. By scheduling virtual frames at the QAP for the sidestream/upstream traffic, all of the sidestream/upstream traffic is perceived by the

5   scheduler as one large downstream frame to be seamlessly scheduled along with the conventional downstream traffic.   According to an aspect of the invention, there is provided a scheduling method based on virtual frames for use in a WLAN. The method comprising the steps of: (a) determining, at said QAP, whether there is at least one upstream traffic stream intended for transmission from said at least one WSTA to said

10   QAP; (b) determining, at said QAP, whether there is at least one sidestream traffic stream intended for transmission from said at least one WSTA to at least one other WSTA; (c) negotiating an intended upstream data rate of transmission, at said QAP, for transmitting said at least one upstream traffic stream from said at least one WSTA, when said determination step (a) is true; (d) negotiating an intended sidestream data rate of

15   transmission, at said QAP, for transmitting said at least one sidestream traffic stream from said at least one WSTA to said at least one other WSTA, when said determination step (b) is true; (e) computing polling and transmission times, at said QAP, for polling said at least one WSTA in accordance with said negotiated upstream and sidestream intended data rates of transmission; (f) generating upstream virtual frames including said computed upstream

20   polling and transmission times and airtimes allocated to the said WSTA, at said QAP, to transmit said at least one upstream traffic stream at said computed polling times; (g) generating sidestream virtual frames including said computed sidestream polling and transmission times and airtimes allocated to said WSTA, at said QAP, to transmit said at least one sidestream traffic stream at said computed polling times; and (h) scheduling the

25   transmission of said upstream and sidestream virtual frames at said computed polling and transmission times.

In the preferred embodiment, the above method is carried out by an QAP comprising a virtual frame generator for determining the time instants when the QAP is required to poll the WSTAs to transmit said upstream and/or sidestream traffic; and a

30   scheduler unit for computing polling and transmission times to poll said at least one WSTA.

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A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIG. 1 illustrates the architecture of a wireless communication system whereto

5 embodiments of the present invention are to be applied;

FIG. 2 illustrates a queue level description of the network of FIG. 1 according to an embodiment of the invention;

FIG. 3 is a block diagram of a QAP according to an embodiment of the invention; and

10 FIG. 4 illustrates a timing diagram to explain the polling procedure according to an embodiment of the invention.

In the following description, for purposes of explanation rather than limitation, specific details are set forth such as the particular architecture, interfaces, techniques, etc., in order to provide a thorough understanding of the present invention. For purposes of

15 simplicity and clarity, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

The inventive method is a scheduling algorithm that utilizes virtual frames for upstream and sidestream scheduling in wireless local area networks (WLANs). The

20 method is intended for implementation by an access point (QAP) in a QBSS network. To the best of the applicant's knowledge, the concept of virtual frames was first introduced in Sunghyun Choi and Kang G. Shin,"A Unified Architecture of Wireless Networks for Real-Time and Non-Real time Communication Services," IEEE/ACM Trans. On Networking, vol. 8, no. 1, pp. 44-59, February, 2000, incorporated by reference herein in its entirety.

25 However, it is believed that the use of virtual frames in the context of wireless LANS has heretofore not been considered. It is to this end that the present application is directed. That is, the method of the present invention introduces the use of virtual frames in the context of wireless LANS, in a manner that enables an QAP to seamlessly operate between granting polls to associated stations (WSTAs) for upstream and/or sidestream traffic and

30 the sending of downstream frames to the WSTAs, as will be described in greater detail below.

FIG. 1 is an illustration of a representative network 100 whereto embodiments of the present invention may be applied. As shown, FIG. 1 illustrates a QBSS network 100 including an QAP 103 coupled to a stationary network 111 and a plurality of stations (WSTA$_1$ through WSTA$_3$) 110, 112, 114. A primary function of the QAP 103 is to
5   facilitate the transmission of data packets. Data packets include "upstream" packets(i.e., packets transmitted in a direction from the WSTAs 110-114 to the QAP 103), labeled as "U", "downstream" packets (i.e., packets transmitted in a direction from the QAP 103 to the WSTAs 110-114), labeled as "D", and "sidestream" packets (i.e., packets transmitted from one WSTA 110-114to another WSTA), labeled as "S". It should be noted that the
10   network shown in FIG. 1 is small for purposes of illustration. In practice, most networks would include a much larger number of mobile WSTAs.

FIG. 2 is a block diagram of one embodiment of a queue level representation of the QAP 103 and WSTAs$_{1-3}$ 110-114 of the network 100 of FIG. 1. As shown, the QAP 103 maintains 9 queues, 8 of which are conventional, Q1-Q8, and a ninth queue, which is the
15   key feature of the invention, referred to hereafter as a virtual queue VQ. Queues 1 through 8 contain real data (i.e., data packets or frames which are transmitted as part of an MPDU). By contrast, the virtual queue VQ contains only virtual frames, as will be described.

Referring now to FIG. 3, a block diagram of the functional elements of the QAP of FIG. 2 are shown. The QAP includes a scheduler 105 which can be broken down into two
20   main functions, traffic stream negotiation 310 and service allocation 320. Traffic stream negotiation 310 further comprises a permission 330 sub-function. The AP further includes a virtual frame generator module 340 for determining the time instants when the AP is required to poll the WSTAs for upstream and/or sidestream traffic. The QAP further includes an admissions control unit 350 for computing in advance, via a scheduling
25   algorithm, polling times to poll each WSTA 110-114 desiring to transmit traffic upstream so as to satisfy the WSTA's 110-114 pre-negotiated data rates.

The present invention is directed exclusively to the scheduling of parameterized QoS traffic. As defined by the IEEE 802.11 standard, parameterized traffic is identified by priority values in the range 8 to 15 which are included as part of a 16 bit QoS control field
30   in the MAC header of each frame. The priority values 8-15 are interpreted as traffic stream identifiers (TSID). Parameterized traffic could include, for example, video telephone, low cost video conferencing, imaging, High Definition Television (HDTV), streaming audio

and/or video and so on. Each of the afore-mentioned applications may place different demands on the wireless communications network 100 depending upon their respective bandwidth requirements. That is, some applications described above are more bit intensive than others (e.g., an HDTV video stream at 24 Mbps). In general, most real time

5   applications qualify as being bit intensive and as such place high demands on the transmission network 100. Other applications, such as stereophonic audio which is typically transmitted at 128 Kbps is comparably less bit intensive and consequently less demanding on the network 100 resources. Therefore, a mechanism is needed to efficiently schedule these disparate network demands for processing by the network 100.

10   To perform scheduling in an efficient manner at the QAP 103, the scheduler 105 must control two processes: (1) determine the existence of any upstream streams that the WSTAs 110-114 intend to transmit to the QAP 103 (2) determine if there is data required to be sent downstream from the stationary network 111, via the QAP 103, to the WSTAs 110-114. The first process is achieved in a polling operation performed by the scheduler

15   105 at the QAP 103. In the polling operation, the scheduler 105 determines which WSTAs have traffic streams to be transmitted upstream to the QAP 103. Once it is determined by the scheduler 105 that one or more WSTAs 110-114 have traffic streams to be transmitted upstream to the QAP 103, a negotiation session is conducted between the QAP 103 and the one or more WSTAs 110-114 intending to transmit data upstream. The negotiation session

20   is conducted by the traffic stream negotiation unit 310 of the QAP 103

          As part of the negotiation session, a permission protocol is invoked by the QAP 103 to grant permission to the requesting WSTA. A permission unit 330 is shown in Fig. 3 as a sub-process of the negotiation unit 310. Once permission is granted to an WSTA, the negotiation process then proceeds by the requesting WSTA, which has been granted

25   permission, informing the QAP 103 of certain parameters related to the traffic stream to be transmitted, including the data rate and other traffic characteristics. Upon receiving these parameters at the QAP 103, an admissions control unit 350 associated with the QAP 103 (See Fig. 3) collects the parameter data for each traffic stream (i.e., requesting WSTA) compute in advance a time instance for polling the various WSTAs requesting to transmit

30   data upstream to the WSTA, in a manner that satisfies a pre-negotiated data rate. Once the polling times are calculated by the QAP 103, virtual frames are then generated to poll the

WSTAs at the computed time instances. It is noted that the virtual frames are actually polling frames for polling the various WSTAs at the appropriate times.

The following exemplary embodiment is provided to further clarify the method of the invention. Assume, for the purpose of explanation, that there are some numbers of
5   WSTAs 110-114 in the network 100 of Fig. 1 that desire to transmit traffic upstream to the QAP 103. For example, assume WSTA$_1$ 110 needs to send HDTV video at 24 Mbps upstream to the QAP 103 and that WSTA$_3$ 114 needs to send stereophonic audio data at 128 kbps upstream to the QAP 103. As described above, it is the responsibility of the QAP 103 to determine the existence of these intended data streams for upstream transmission.
10   In particular, the admission control unit (ACU) 350 of the QAP 103 determines whether there are any streams from WSTAs 110-114 intended for upstream transmission. Once the QAP 103 is made aware of these traffic streams, the scheduler 300 then negotiates with each WSTA 110-114 having a data stream to transmit upstream, to ascertain the WSTA's intended data rates of transmission (e.g., 24 Mbps for WSTA 110, 128 kbps for WSTA
15   114) as well as other transmission parameters of interest. Once the data rates are determined by the QAP 103, the ACU 350 computes in advance, via a scheduling algorithm, polling times to poll each WSTA 110-114 such that the WSTAs respective pre-negotiated data rates may be satisfied. It is noted that the details of the scheduling algorithm for negotiating the respective data rates are not central to the instant application
20   and as such will not be discussed further.

Polling frames are then generated by the scheduler 105 based on the computed polling times of the upstream or sidestream sessions. The virtual frame generator in the QAP 103 uses this schedulable information and inserts into the virtual frame queue (VQ) the virtual frames with a time instance when they need to be exactly transmitted onto the
25   channel. For the scheduler this basically takes into account all of the upstream and sidestream sessions.

The scheduler now uses this virtual frame queue (VQ) and the conventional downstream frame queues Q1-Q8 to schedule downstream sessions or upstream and/or sidestream sessions accordingly. It is noted that there is a QoS guarantee on satisfying the
30   intended data rates, however, the method of the invention is more sophisticated than a 'best efforts' attempt of the prior art.

·Referring now to FIG. 4, a timing diagram illustrating the polling times computed at the QAP 103 for the exemplary embodiment in which it is assumed that two WSTAs 110, 114 intend to transmit data upstream to the QAP 103 at data rates of 24 Mbps and 128 Kbps, respectively. First, with regard to $WSTA_3$ 114, assuming a packet size of 128 bits,

5   to satisfy a data rate of 128 kbps, $WSTA_3$ 114 must send a packet every 1 ms. Similarly, assuming a packet size of 2400 bits, to satisfy a data rate of 24 Mbps, $WSTA_1$ 110 must send a packet every 100 μs. Therefore, the ACU 350 must poll $WSTA_1$ ten times (10x) as often as $WSTA_3$ 114.

FIG. 4 illustrates that the ACU 350 of the QAP 103 polls $WSTA_3$ ten times as often

10   as $WSTA_1$ 110. It should be noted that the time intervals T1 – T10 are not equidistant time intervals but are instead calculated in accordance with the scheduling algorithm so as to satisfy the intended data rates. As shown, at each polling instance along the time line (e.g., T1 through T10), $WSTA_3$ 114 is polled for a time duration denoted as "x" and $WSTA_1$ 110 is polled for a time duration denoted as "y". Time durations, "x" and "y" are not fixed, but

15   are instead dependent on the particular scheduling algorithm used. However, it is not the focus of the present invention to determine time durations x and y. Instead, the present invention is directed to the generation of the virtual frames that have time durations, x, y, associated therewith. It is also noted that these time durations may be extended as necessary if there are additional packets to be transmitted upstream at a particular polling

20   interval.

Thus far, a process for sending upstream and/or sidestream traffic has been discussed. However, the present invention is equally directed to a concurrent process. That being the transmission of frames downstream from the stationary network 111, via the QAP 103, to the one or more WSTAs 110-114. In accordance with this process, the

25   WSTAs 110-114 make various data requests from the stationary network 111 for data which could include, for example, any of the parameterized data categories discussed above (e.g., video telephone, low cost video conferencing, imaging, High Definition Television (HDTV), streaming audio and/or video and so on). To satisfy these data requests at the required data rates, the QAP 103 must perform the steps discussed above

30   which generally include performing a scheduling computation to determine polling times and generate virtual frames therefrom. The steps required to send traffic downstream are

identical to those previously described for sending traffic upstream with the only notable distinction being the direction of the intended traffic.

An advantage of the invention is that the QAP 103 is able to seamlessly grant polls (i.e., virtual frames) for the upstream and/or sidestream traffic and simultaneously send downstream traffic to the WSTAs.

The foregoing is to be constructed as only being an illustrative embodiment of this invention. Persons skilled in the art can easily conceive of alternative arrangements providing a functionality similar to this embodiment without any deviation from the fundamental principles or the scope of this invention.